Factors Influencing the Acoustic Behavior and Nearshore Residence of the Gray Whale (*Eschrichtius Robustus*) Along Their Migration Route

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LONG-TERM GOALS

Our long-term goal is to quantify the acoustic behavior of gray whales in the coastal waters of the Northeast Pacific Ocean and to characterize the link between coastal residency patterns of these migratory mammals and the distribution of hyperbenthic swarms of their primary prey (mysids).

OBJECTIVES

Several years of observations off the Oregon coast have revealed considerable interannual variability in the residence patterns of gray whales as well as in foraging behavior (Newell and Cowles 2006). For

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example, during the summer of 2005, the resident gray whale population had 50% fewer individuals than the previous three summers, and those 2005 residents displayed many fewer characteristic feeding behaviors than residents in other summers. This variability in residency and foraging was likely due to changes in the distribution and abundance of swarms of benthic mysids, the gray whale's preferred prey in this region. We have observed that the resident gray whales repeatedly forage on discrete hyperbenthic mysid swarms throughout the spring and summer months (late April – late September). As described in Newell and Cowles (2006), these discrete concentrated swarms can be found along the 10-15 m isobath off the central Oregon coast, and interannual variability in swarm thickness and extent appears to be associated with the timing and intensity of coastal upwelling. In early summer 2005, mysid swarms were less than 1 m thick, approximately 20-30% as thick as in 2003 and 2004, likely limited by the late onset of coastal upwelling and local production (Pierce et al. 2006). These observations strongly support the hypothesis that the ecological link between ocean conditions and mysid swarm dynamics affects the spatial and temporal distribution of both migrating and resident gray whales in the eastern North Pacific. We will quantify this link between ocean conditions, mysid swarms, and gray whales through a pilot project that will assess the frequency and duration of nearshore residence and the acoustic and foraging behavior of *E. robustus* along the Oregon coast, as well as the distributional dynamics of the mysid prey.

The project objectives are to:

- characterize the spatial limits for passive acoustics to identify and locate gray whales during their residency (and foraging) along the central Oregon coast;
- determine what aspects of mysid swarm dimensions and concentration can be characterized with active acoustic moorings and localized surveys with small boats;
- document the time scales of variability in mysid swarm characteristics that influence the foraging time scales of the gray whales.

APPROACH

We used a focused, month-long observational program during July and August of 2010 that used a variety of observational approaches, linking time series from moored passive and active devices with spatial surveys of prey availability. In addition, during the coming months, we will be incorporating local and regional observations of ocean properties from complementary programs (PISCO, CMOP, OrCOOS) along with visual surveys of resident gray whales that were conducted during surveys of mysid swarms. The results of our pilot project will provide a rigorous test for the application of passive and active acoustics to localize marine mammals in relation to their prey fields, and could lead to longer-term deployments that would enhance our understanding of gray whale responses to the nearshore environment.

The month-long observational program was based on an array of sensors installed in shallow water over the Oregon continental shelf (Figure 1). Moored passive acoustic sensors (one example in Figure 2) documented the patterns of distribution of the resident gray whales. Moored active acoustics (A1 to A3 in Figure 1) with temperature sensors were used within regions of dense hyperbenthic swarms of mysids (the primary prey for the resident gray whales to document a continuous record of variability in

mysid concentrations. We used a small boat with active acoustics and ADCP to conduct frequent spatial surveys (Figure 1) of the dimensions and variability in the hyperbenthic mysid swarms.

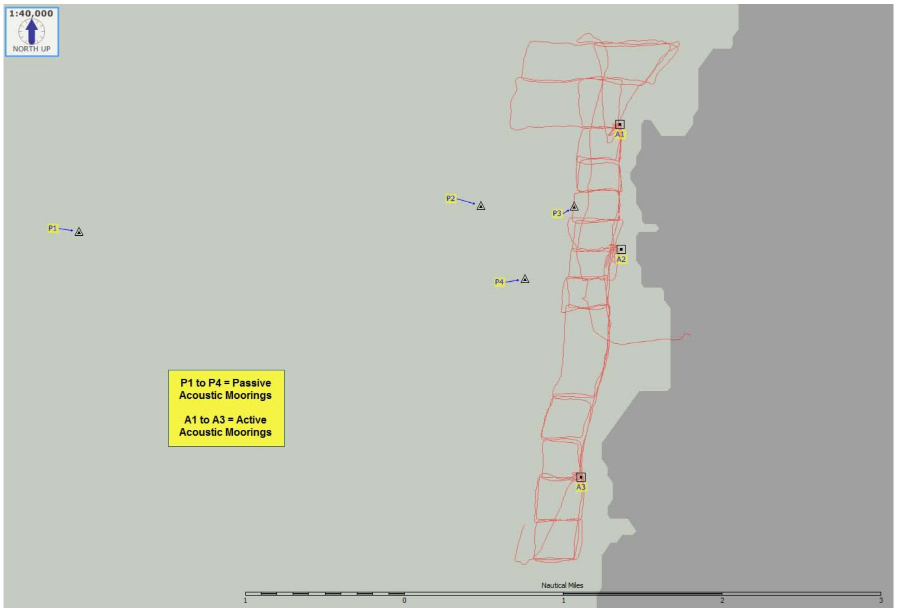

Figure 1. Diagram of the mooring distribution off the central Oregon coast. Along the 10m isobath we deployed three echosounders (A1 to A3) along a 2.5 nm line that bracketed the entrance to Depoe Bay OR. We also deployed an array of three passive sensors (P1 to P3) just west of the central echosounder and ADCP. A fourth passive sensor was deployed about 3 nm west of the central echosounder. Also noted on this graphic is the ship track followed during one day of surveying with multi-frequency acoustics and ADCP to assess the dimensions of the mysid swarms found in patches along the 10m isobath. CTD and net deployment were conducted frequently during each line survey.

Figure 2. Configuration of a passive acoustic sensor within its mooring frame. See Figure 1 for the distribution of four of these sensors across the study area.

WORK COMPLETED

For a period of 5 weeks in July and August of 2010, 3 upward looking moored echosounders were deployed in conjunction with an array of passive acoustic sensors. Two of the echosounders sampled at 420 kHz while the center instrument sampled at 200, 420, and 730 kHz. All echosounders operated at a 1 Hz sampling rate with a vertical resolution of 5 cm. Periodically throughout the mooring period, sampling was also conducted from a research vessel with 5 echosounder frequencies (70, 120, 200, 333, 710 kHz) to reveal the abundance, distribution, and size of mysids. Acoustic sampling was complemented by vertically integrated net tows and video camera and CTD profiles.

RESULTS

A small subset of data collected with the shipboard echosounders is shown in Figure 3. Mysids were highly aggregated in dense bottom-associated features that often covered more than half of the water column vertically and sometimes reached all the way to the surface. These aggregations were found between 10 m of water where sampling began and 20 m where they abruptly ended. Net tows revealed that the size of mysids in these aggregations ranged from 1 to 3 cm with some aggregations containing a range of size classes while others were monospecific with respect to size.

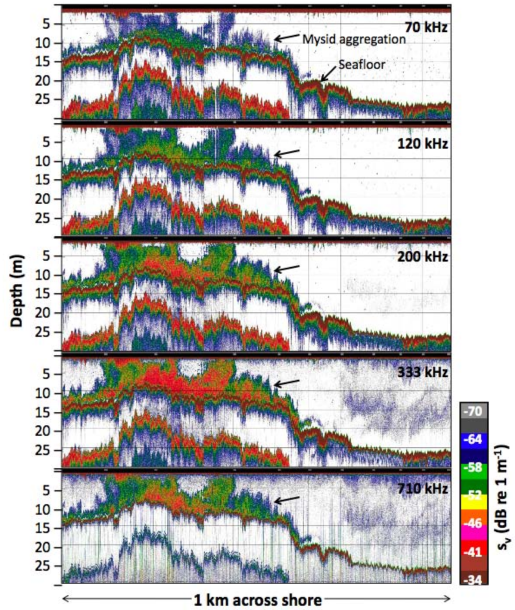

Figure 3. Acoustic backscatter from shipboard echosounders at five-frequencies show the highly aggregated distribution of mysids and the abrupt end of these aggregations at water depths of around 20 m. The frequency response can be used to estimate the size class of mysids throughout the aggregation.

Gray whales were observed at frequent intervals within the study region and those observations were documented to day, time, latitude, longitude, type of foraging behavior, and if the observed whale was a local 'resident', based on comparison of body characteristics with those in the photo-ID library of resident gray whales of the central Oregon coast. Data analysis of the passive acoustic data will link those direct visual observations with the vocalizations found within the passive acoustic data. The active acoustic data from the moorings will provide a time series of mysid swarm thickness at three fixed locations, and will be correlated with the multiple spatial surveys conducted during three intensive weeks of survey work while the moorings were deployed.

We obtained bottom temperature records at the three active acoustic moorings (8.25 inches above the bottom, approximately 10m water depth), and have derived the surface wave elevation from the bottom pressure record recorded by the Nortek AquaDopp Profiler hourly (burst sampling, 512 samples per burst, 2 Hz). Waves were derived from the bottom pressure record using linear wave theory. The bottom temperature record (Figure 4) revealed strong upwelling characteristics at beginning of the deployment with intervals of warming and subsequent cooling during the month-long deployment. It is interesting to note that the mysid swarm locations were subject to 1-2^o C temperature variations within a tidal cycle at the 10m isobath.

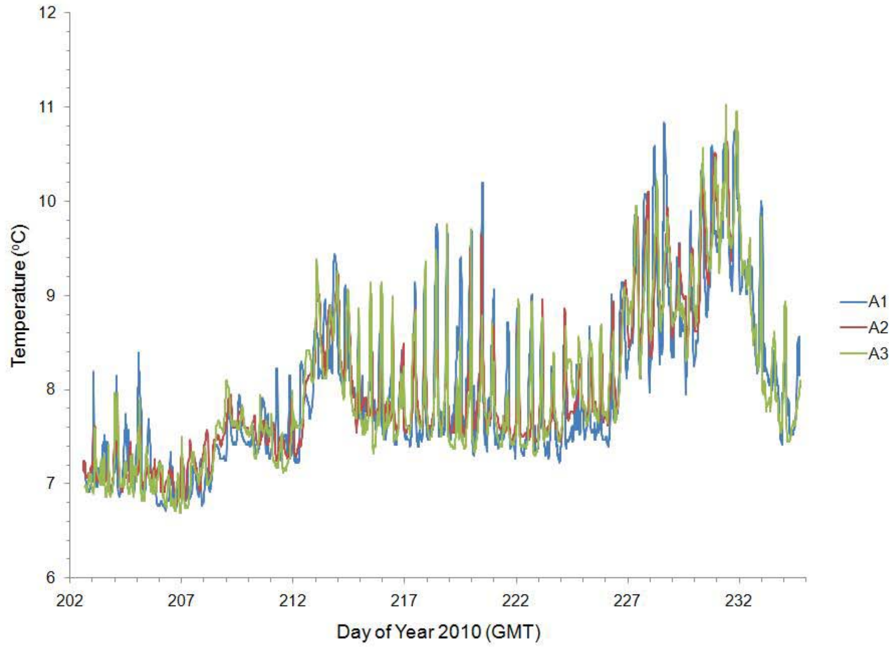

Figure 4. Times series of 10m temperatures at the three moorings sites (A1 to A3) shown in Figure 1.

IMPACT/APPLICATION

We anticipate that this work will illustrate the need to characterize ocean conditions and prey distribution patterns in order to fully understand the acoustic and foraging behavior of marine mammals.

TRANSITIONS

None at this time.

RELATED PROJECTS

ONR grant N00014-08-1-1082, "Automatic Detection of Beaked Whales from Acoustic Seagliders", includes the development of methods for automatically detecting odontocete clicks. Although odontocetes are not part of this gray whale project, the passive acoustic sensors record all ambient sound, and thus may provide incidental information about the occurrence and population density of the lower-frequency odontocetes present, including killer whales (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*).

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PUBLICATIONS (refereed)

None

HONORS/AWARDS/PRIZES

Dr. Benoit-Bird has received a number of prestigious awards over the past few years, most notably a MacArthur Fellowship in 2010.

2007 **Kavli Frontiers Fellow,** National Academy of Sciences

2008 **Ocean Sciences Early Career Award,** American Geophysical Union

2009 **R. Bruce Lindsay Award,** Acoustical Society of America

2010 **MacArthur Fellowship**, John D. and Catherine T. MacArthur Foundation